CLAIMS

What is claimed is:

1. A method of etching a copper containing material, comprising:

contacting the copper containing material comprising at least about 10 % by weight copper with a first solution to convert at least a portion of the copper containing material to a passivating film, the first solution comprising a peroxide compound, a first organic acid, and water; and

contacting the passivating film with a second solution to remove the passivating film, the second solution comprising a second organic acid and water.

2. The method of claim 1,

the peroxide compound is selected from the group consisting of one or more of barium peroxide, benzoyl peroxide, carbamide peroxide, cumene hydroperoxide, di-t-butyl peroxide, hydrogen peroxide, potassium peroxide, and sodium peroxide; and

the first organic acid and the second organic acid independently selected from the group consisting of one or more of formic acid, acetic acid, propionic acid, butyric acid, pentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, dichloroacetic acid, trichloroacetic acid, trifluoroacetic acid, perfluoroacetic acid, perfluorooctanoic acid, oxalic acid, malonic acid, succinic acid, fumaric acid, glutaric aicd, itaconic acid, ethylenediaminetetraacetic acid, citric acid, ascorbic acid, maleic acid, malic acid, dimethylphosphoric acid, dimethylphosphinic acid, methanesulfonic acid, trifluoromethanesulfonic acid, ethanesulfonic acid, 1-pentanesulfonic acid, 1-hexanesulfonic acid, 1-heptanesulfonic acid, benzenesulfonic acid, benzenedisulfonic acid, tolulenesulfonic acid, naphthalenesulfonic acid, tropolone, benzoic acid, and picric acid.

3. The method of claim 1, wherein the first solution comprises from about 1 % to about 50 % by weight the peroxide compound, from about 0.001 % to

about 10 % by weight of the first organic acid, and from about 30 % to about 98 % by weight of water.

4. The method of claim 1, wherein the first solution further comprises at least one of a surfactant, a pH adjuster, and an ionic salt.

5. The method of claim 1, wherein the second solution comprises from about 0.001% to about 10% by weight of the second organic acid and from about 50 % to about 99.9 % by weight of water.

6. The method of claim 1, wherein the second solution further comprises at least one of a surfactant, a pH adjuster, and a biocide.

7. The method of claim 1, wherein the first solution has a pH from about 2 to about 6.5 the second solution has a pH from about 1 to about 6.

8. The method of claim 1, wherein the first solution has a temperature from about 5 °C. to about 50 °C. the second solution has a temperature from about 20 °C. to about 90 °C.

9. The method of claim 1, wherein the passivating film comprises copper oxide.

10. A method of etching a copper structure, comprising:

contacting the copper structure comprising at least about 25 % by weight copper on a wafer with a first solution to convert at least a portion of the copper structure to a passivating film, the first solution comprising a peroxide compound, a first organic acid, and water;

contacting the passivating film with a second solution to remove the passivating film, the second solution comprising a second organic acid and water, the

second solution having a lower pH and a higher temperature than the pH and temperature of the first solution; and

rinsing the wafer with water to provide an etched copper structure.

11. The method of claim 10, wherein the first solution comprises from about 2 % to about 40 % by weight the peroxide compound, from about 0.01% to about 5% by weight of the first organic acid, from about 40% to about 95% by weight of water, from about 0.01 % to about 20 % by weight of a surfactant, and from about 0.001% to about 5% by weight of a pH adjuster.

12. The method of claim 10, wherein the second solution comprises from about 0.01% to about 5% by weight of the second organic acid, from about 70% to about 99.5% by weight of water, from about 0.001% to about 5% by weight of a biocide, and from about 0.001% to about 5% by weight of a pH adjuster.

13. The method of claim 10, wherein the second solution comprises at least two organic acids.

14. The method of claim 10, wherein the first solution contacts the copper structure for a time from about 1 second to about 200 minutes and the second solution contacts the passivating film for a time from about 1 second to about 200 minutes.

15. The method of claim 10, wherein the first solution further comprises a nonionic water soluble polymer surfactant.

16. The method of claim 10, wherein the etched copper structure has an R_{tm} of about 50 Å or less.

17. A method of etching a copper containing material, comprising:

contacting the copper containing material with a first solution to convert at least a portion of the copper containing material to a passivation layer, the first solution comprising a peroxide compound, a first organic acid, and water;

contacting the passivation layer with a second solution to remove the passivation layer, the second solution comprising a second organic acid and water;

and simultaneously

monitoring the formation and removal of the passivation layer using a scatterometry system by generating a signature associated with forming and removing the layer, comparing the signature to a signature library to determine layer depth, and terminating forming and removing the passivation layer when a desired depth is attained.

18. The method of claim 17, wherein generating the signature associated with forming and removing the passivation layer comprises directing a beam of incident light at the passivation layer, collecting light reflected from the passivation layer, and transforming the reflected light into the signature.

19. The method of claim 17, wherein a closed loop feedback control system for terminating the formation and removal of the passivation layer according to the determined depth comprises feeding information related to passivation layer depth via the closed loop feedback control system to a first and second solution controller, wherein the first and second solution controller is connected to a trained neural network to facilitate termination of the formation and removal of the passivation layer.

20. The method of claim 17, wherein the scatterometry system further compares the signature to a signature library to determine passivation layer profile, and terminates forming and removing the passivation layer when a desired passivation layer profile is attained.